Valuation of open space: hedonic house price analyses in the Dutch Randstad region

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VALUATION OF OPEN SPACE

Hedonic house price analyses in the Dutch Randstad region

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Abstract
In this paper, we aim to reveal the monetary value of open space by using a hedonic pricing model of residential property values. The analysis is supported by the use of Geographic Information Systems (GIS). We present three local Dutch housing market case studies in the Randstad region. In all studies we distinguish open space on three different scale levels, ranging from a view of a small local open space to the proximity of large regional open space for recreational purposes. We find that a view of open space, *ceteris paribus*, increases house prices 4 to 8 percent. We also observe that the availability of local open space within 25 metres of residences has a substantial positive impact on house prices. In two of the three selected housing market areas this positive impact is even found up to 50 metres. The contribution of larger areas of regional open space to house prices cannot be established unequivocally, as its impact ranges from positive to negative depending on the studied area.

Key words: Land use; open space; valuation; hedonic price theory; GIS.
JEL classification: C51, C53, R14, Q24

1. INTRODUCTION

Land-use planning in essence tries to reconcile the various, often diverting interests of different stakeholders. This is an especially complex task in the heterogeneous landscape surrounding the bigger cities in metropolitan areas. This landscape consists of green, open areas adjacent to and enclosed by the urban environment. Changes in this landscape are a delicate matter, because they affect sustainability, the environment and scenic quality, as we see in processes like urban sprawl, intensive outdoor recreation, city expansion and additional investments in infrastructure. One of the major planning concerns here is to do justice to the specific value that society associates with the open space that surrounds cities. This value and the ensuing externalities have received limited attention in the theoretical literature on urban land use based on the seminal works of Alonso (1964), Muth (1969) and Fujita (1989). More recent economic literature, however, suggests that the presence of open space improves urban living conditions and individual well-being (see, for example, Luttik, 2000; Geoghegan, 2002; Ward Thompson, 2002; Chiesura, 2004 and Mansfield *et al.*, 2005).

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The lack of a clear monetary value makes green, open areas vulnerable to construction activities and infrastructure. Such use of open space entails imposing externalities of certain actors on others, but since the market value of open space does not fully reflect its societal value, these externalities are market failures that call for corrective measures by the public sector in the form of land-use interventions or pricing measures. However, failure of governmental correction impedes effective market co-ordination. Incorporation of the public interest in open space in metropolitan planning requires quantitative valuation of this asset. This can help policy makers improve their decisions. The difficulty with this is of course that environmental and general societal values are normally not traded, and hence no market price can be observed that would reflect or approximate marginal costs or benefits.

In the past decade, economists have developed a number of procedures that, at least in the case of some externalities, provide reasonable estimates of the monetary value of some of the amenities of open space, despite the remaining uncertainty and dispersion in values produced (see for example Button, 1993). In recent years the level of sophistication used in this process has risen considerably, for example in the work on transport externalities by Friedrich and Bickel (2002) and by Mackie and Nellthorp (2001). However, some limitations remain, partly because the valuation of severance and visual intrusion is hampered by many complications. These especially include difficulties in objective quantification, uncertainties on the impacts on human and ecological communities, and colinearity with other pressures on the metropolitan open space (for example noise disturbance from infrastructure). Furthermore, some environmental cost categories, for example the fragmentation effects of infrastructure and urban development, have not received due attention in valuation studies. As a result, such effects are often not fully included in metropolitan planning. The current analysis attempts to take such effects into account in order to valuate open space in a systematic and integrated way. In this paper, we first present our methodological-technical design. Subsequently, we define the concept of open space and make it operational on various scale levels and at different distance ranges. Then, we attach a monetary value to it using three separate hedonic house price analyses at the local housing market level in the Randstad region, the strongly urbanized western part of the Netherlands. The studies are set up to investigate the effect of the presence of open space on house values. The final section summarises the results and discusses their implications for open space preservation policies.

2. METHODOLOGICAL-TECHNICAL DESIGN

As it will not be possible to estimate monetary values for all different dimensions of open space, the research focuses on those aspects that can be related to the appreciation of individual residents of the metropolitan landscape. These are the so-called 'use values' that humans attach to open space on the basis of their own, direct interest. In this research we focus on the added value of the availability of open space on residential property that we aim to reveal through a hedonic house price analysis. The valuation of specific cultural, natural and recreational characteristics of open space by potential visitors is part of a related ongoing study that will use a stated preference analysis.

Revealed preference valuation, for example through the selected hedonic pricing method, has the advantage of potentially capturing all utilities associated with open space based on observed human behaviour, rather than having to trust *stated preferences* that are limited to the specific utilities included in such surveys. The added value of open space observed in a hedonic price analysis is a combination of all positive and negative characteristics that house buyers associate with open space. Foreseen limitations – and hence challenges – of the selected method include that it may be difficult to separate, empirically, the proximity to open space from possible associated external costs (e.g. lack of facilities), to distinguish these effects from other relevant factors that vary over space, to control for the impact of land-use regulation on house prices, and to account for heterogeneity and self-selection of individuals in their location decisions. For an adequate analysis, it is thus important to pay attention to issues of spatial dependence (see for example Buurman, 2003; Van der Kruk, 2005). This section first introduces our conceptualisation of open space and subsequently describes its implementation in the hedonic price analyses of this study. The model outcomes are presented in the subsequent section.

2.1 Defining open space

Open space is a broad concept that lacks a clear unambiguous definition. In the Dutch national planning practice open spaces are usually considered to be large areas with few visual obstacles that allow a free view over a relatively large area (see for example LNV, 2002; VROM *et al.*, 2004). Buildings, high-rising vegetation and height differences may disturb this panoramic view. Single objects (high voltage masts or wind mills) can also severely affect the experience of open space. In this visual concept of openness, infrastructure is, generally, not considered to be an important disturbance factor. Only specific types of elevated infrastructure, such as flyovers, bridges or roads on a dike, are thought to have a strong visual influence and are therefore considered as an intrusion on openness.

This essentially visual interpretation of openness can be demonstrated through the work of the Dutch research institute Alterra (e.g. Alphen *et al.*, 1994; Farjon *et al.*, 2004). In their approach, the degree of openness is based on the height of landscape elements. By using detailed geographical data sets they assess the amount of buildings and high-rising vegetation per grid cell of 250 x 250 metres. Their scale ranges from a very open landscape (the typical Dutch polders) to a non-open landscape consisting of forests (see Figure 3-1, left-side image). Villages and cities rank in between, being classified respectively as moderately open and closed landscapes. This definition corresponds with the spatial planning perspective of open space as a crucial element of spatial quality indicators such as spatial and cultural diversity (VROM, 2000). These indicators stress the importance of a visually open landscape to preserve the contrast between rural and urban areas and to retain the cultural and historical values that are attached to it. This visual concept of openness, however, produces the remarkable result that extensive woodlands without much human presence are considered to be less open than the big Dutch cities. This definition is difficult to combine with the public appreciation of the non-urban landscape that is at the heart of our valuation study.

Studies into the general appreciation of the landscape (e.g. Roos-Klein Lankhorst *et al.*, 2002) show a positive influence of the presence of natural land-use types, relief and water, whereas urbanisation, noise and visual disturbance have a negative impact on the perception of the landscape. The general public thus essentially confronts the busy, urban areas with the quiet, green countryside. As our goal is to valuate open space from a human user perspective, we will adopt this perceptional view on open space instead of the strictly visual approach that is more common in Dutch spatial planning. Open space is thus defined as 'being free of buildings and other proofs of human presence' (e.g. greenhouses or infrastructure). This concept of openness corresponds roughly to the inverse of urbanisation (see Figure 1, right-side image). The least urbanised areas in this figure can be considered as open spaces. The two pictures in Figure 1 clearly show the divergent outcomes of the two alternative interpretations of open space.

Another crucial element in our definition of open space is spatial scale. Green, open areas exist on different scale-levels and each has its own importance for the metropolitan citizen. We distinguish three different levels:

1. *house level*: small patches of open space that can be viewed from a home, offering a continuous diversion from urban living conditions;
2. *local level*: small or large patches of open space within walking distance (several hundred metres), that can, for example, be used daily for walking the dog or as a children's playground; and

3. *regional level*: large open spaces in which residents can escape from the urban bustle, e.g. for outdoor activities in the weekend. To actually appreciate openness in these areas we expect a minimum dimension of 500 hectares to be relevant.

All types of open space are under continuous threat of further urbanisation: small inner-urban open spaces are claimed in densification processes, whereas more extensive urban expansions are found in the larger open spaces surrounding cities. These threats make the valuation of open space crucial for helping metropolitan planners to better assess its societal values. Recent economic literature has seen a steady increase in valuation studies on open space at the local level (for an overview, see Brander and Koetse, 2007). We are particularly interested in the value of regional open space, because of its potential planning implications. The valuation of open space at lower scale levels, however, is also included in our study to give a full account of the importance of open space. It, furthermore, serves as a reference point for the observed values at the regional level.

An additional concern to include in the definition of regional open space is disturbance, since this aspect is considered to significantly influence the human perception of open space. We will therefore take into account the fragmentation of open landscape elements by the presence of motorways and related disturbance through traffic noise. Other sources of disturbance, such as stench, light and visual disturbances are excluded from the analysis because these are either considered to be less important to the general perception of openness or are difficult to quantify objectively. Neither are legal issues (e.g. land ownership rights of the open spaces) considered, as these are not deemed directly relevant for the valuation of open space: people can enjoy the amenities of open spaces (beauty, view, scent, flora, fauna et cetera) regardless of who owns the property. For operational reasons accessibility, shape and type of the open areas are also excluded from the analysis.

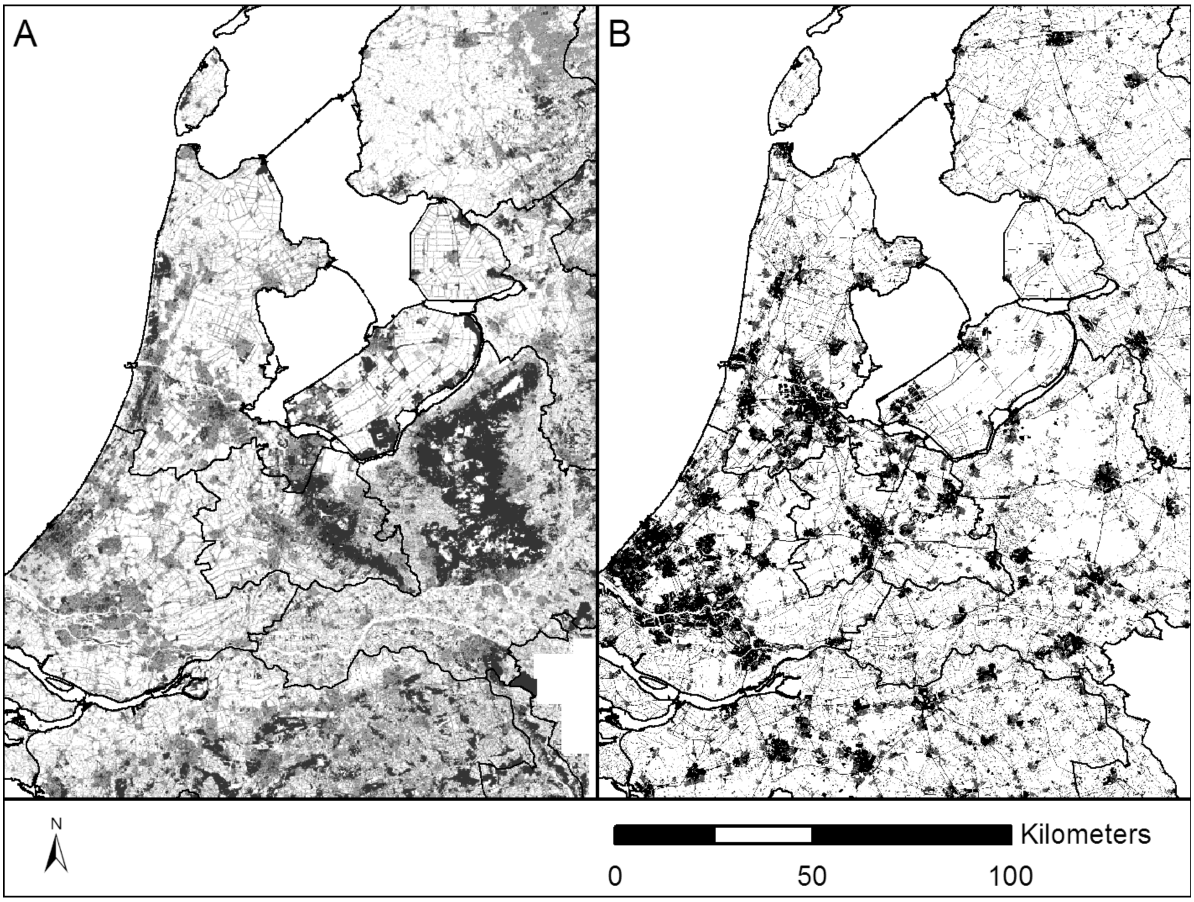

Figure 1. The visual (left) and perceptional (right) interpretation of openness in the central part of the Netherlands. The darker colours denote an increase in closed landscape elements (left) or urban land-use types

(right). Figure adapted from the KELK and *Land Use Scanner* models (Farjon *et al.*, 2004; Borsboom-van Beurden *et al.*, 2005).

2.2 Hedonic house price analysis

House prices are determined by the moment and type of transaction, the structural characteristics of the sold object and its locational or spatial characteristics. Since all these characteristics are embedded in a single house sale transaction, they only have an implicit value. The hedonic pricing method determines the *implicit* value of non-tradable characteristics of goods by analysing the *observed* value of tradable goods that incorporate all or part of those non-tradable characteristics. Taylor (1916), Waugh (1928) and Court (1939) first applied this method. Lancaster (1966) provided the theoretical justification, while the method was first described in a general framework by Rosen (1974). The main strength of the hedonic pricing method is that values can be estimated based on actual choices. The method can provide a detailed quantitative valuation of a wide range of structural and spatial characteristics when reliable transaction data and spatial data are available. A limitation of the method is that it assumes perfect competition, fully informed actors and no transaction costs when actors choose to relocate. This is an obvious simplification of reality where, for example, zoning restrictions create artificial submarkets. Furthermore, not all actors have the same information available, causing some value-affecting characteristics to stay unperceived. Actual house prices may thus deviate from expected, theoretical values. For a more detailed overview of advantages and limitations of the hedonic pricing method, we refer to King and Mazotta (2005). An in-depth summary of this specific technique is presented by Griliches (1971).

2.3 Model formulation and selection of variables

The basic regression model used in this analysis to explain house prices is formulated as follows:

$$P = \alpha + \beta S + \gamma L + \tau G + \varepsilon \qquad (1)$$

where P is an (n x 1) vector of house prices, S is an (n x i) matrix of transaction-related characteristics, L is an (n x j) matrix of structural characteristics, G is an (n x k) matrix of spatial characteristics, α; β; γ; τ are the associated parameter vectors and ε is an (n x 1) vector of random error terms. The functional form and the identity and number of variables of the model can be determined using econometrics and statistical analysis. For this analysis, we choose to estimate a loglinear model, since this functional form is widely used in similar studies and thus allows for a straightforward comparison of results.

A quick-scan of recent hedonic pricing studies that include landscape characteristics in the explanation of residential property values (Table 1) indicated the following structural characteristics of a house to be significant: type (e.g. apartment, single-family home, villa), age, material/structure (mostly brick or wood), size (e.g. floor-area in square metres and/or volume in cubic metres), number of rooms, number of bathrooms, presence of a fireplace, presence/length/position of a garden. All these elements were included as separate explanatory variables in our study with the exception of material/structure that is considered less relevant in the Netherlands because of its relative uniformity in building materials compared to the United States to which most of the selected studies refer.

The quick-scan also resulted in an extensive list of spatial characteristics that were found to be significant in one or more studies (Table 1). For a more extensive overview of environmental valuation studies, see Van Leeuwen (1997) and Ruijgrok (2004). The provision of services is included in an urban attractivity index that describes the availability of cultural, catering and retail facilities on a 0 to 1 scale in 500 metre grid cells. The analysis also incorporates accessibility measures in the form of Euclidean distance to railway stations and motorway ramps. The negative externalities associated with infrastructure (e.g. noise disturbance) are included in two dummy variables that describe the presence of a railroad or motorway within 500 metres.

Table 1. Overview of spatial variables impacting house prices in selected publications

Variable	Studies
Distance to city	Bastian *et al.* (2002), Geoghegan (2002), and many more
Distance to local shopping centre	Mathis *et al.* (2003)
Historical value of a neighbourhood/a house	Mathis *et al.* (2003), Ruijgrok *et al.* (2004)
Neighbourhood quality (measured by proxies as population composition, average income)	Geoghegan *et al.* (1997)
Distance to public transport station	Mathis *et al.* (2003)
Distance to/Disturbance from school/college	Powe *et al.* (1995)
Distance to/Disturbance from major road	Geoghegan *et al.* (1997), Powe *et al.* (1995)
Noise	Bateman *et al.* (2002), Mathis *et al.* (2003), Oosterhuis and Van der Pligt (1985)
Percentage of high voltage masts/wind mills	Mathis *et al.* (2003)
Residential land use (percentage)	Geoghegan *et al.* (1997)
Scenic view (adjacent to garden/ public green/ forest/ open space/ water *et cetera*)	Bastian *et al.* (2002), Garrod and Willis (1992), Geoghegan *et al.* (1997), Luttik (2000), Mathis *et al.* (2003), Tyrväinen (1997), Tyrväinen and Miettinen (2000)
Natural amenities (a.o. value increase due to the creation of new nature/recreation areas)	Geoghegan *et al.* (1997), Briene *et al.* (2001), Ruijgrok *et al.* (1999)
Distance to/View of forest	Mathis *et al.* (2003)*, Tyrväinen (1997), Tyrväinen and Miettinen (2000)*, Morales (1980), Powe *et al.* (1995)
Distance to local and/or regional park	Bervaes and Van den Berg (1995)**, Fennema (1995) [2], Hammer *et al.* (1974)***, More *et al.* (1988), Van Leeuwen (1997), Weicher and Zerbst (1973)
Distance to green (local and regional scale)	Sijtsma *et al.* (1996)
Open space (various types and distances)	Ready and Abdalla (2005), Geoghegan (2002), Powe *et al.* (1995)
Open space (percentage)	Geoghegan *et al.* (1997), Geoghegan (2002)
Fragmentation of land uses	Geoghegan *et al.* (1997)

Note: * Only significant at distances smaller than 600 metres; ** Including both view of and/or distances to a park up to 400 metres; *** Includes distances to a park up to 800 metres.

To make our definition of open space (Section 2.1) operational, a detailed GIS vector land-use map is used (CBS, 2002). From this data set we select the open land-use types (agriculture, nature, water and/or recreation[2]) that, in combination with the exact locations of the sold objects, allow for the distinction of open space at the three selected spatial scale levels. View of open space is associated with the objects that are located within or directly adjacent to an open land-use type. The proximity to local open space is inferred from the availability of any size of open space within 10 to 100 metres from the sold object. In initial model specifications open-space availability at larger distances (up to 300 metres) turned out to be irrelevant. Regional open space is defined as being a generalised area of interconnected open land-use types with two additional characteristics. First, a data layer with the national motorway system is overlaid on the generalised open-space areas to exclude the locations that are disturbed by the presence of the motorways. In a second step the remaining contiguous areas of at least 500 hectares are selected.

[2] From these main land-use types we exclude greenhouse agriculture because of its specific built-up appearance. Large water bodies are excluded in the regional open space definition as they cause individual terrestrial open spaces to be considered as extremely large contiguous areas. Note that for most land-use types areas of less than 1 hectare are not included in the original data set, meaning that very small patches of open space are excluded from the analysis.

In the hedonic regression model these three levels of open space are implemented as follows. View of open space and presence of local open space are expressed in a series of dummies that indicate whether or not open space is available within five different distance ranges (0-10m, 10-25m, 25-50m, 50-75m and 75-100m). The 0-10 metres class is considered to represent view of open space, the other four classes represent the presence of local open space. The availability of regional open space is described in one continuous variable that describes the Euclidean distance to the nearest open space area.

The house prices that form the dependent variable in our analysis are organised in a spatial database. The prices and the associated transaction and structural characteristics of the objects sold, are kindly provided by the Dutch Association of Real Estate Brokers (NVM). All individual objects are given a geographical location (X- and Y-coordinates) based on the available address-information. Geographical Information Systems (GIS) are used to describe the spatial characteristics. As the focus of this paper is on the relevance of spatial factors for house prices only, time-series problems are avoided by using observations from a limited number of years (1997-2001) and by using time dummies that incorporate, amongst others, price and interest changes during this period. Table 2 provides a complete overview of the data sets incorporated in the analysis.

Table 2. Summary statistics for the three local case studies (period: 1997-2001)

Variable	Amsterdam	Leiden	Het Gooi
Total number of observations	20,114	7,137	9,597
Average transaction price (€)	202,734	168,369	253,981
Idem per square metre (€/m^2)	2,045	1,478	1,440
Transaction characteristics			
1997 (total number)	4,326	1,696	2,004
1998 (total number)	4,611	1,928	2,279
1999 (total number)	4,766	1,476	2,357
2000 (total number)	5,410	1,764	2,534
2001 January-March (total number)	1,001	273	423
Free of transfer tax (0=no/1=yes)	0.009	0.001	0.002
Structural characteristics (average values)			
Building age (years before transaction)	56	45	51
Surface area (m^2)	121	158	308
Number of rooms	3.6	4.1	4.6
Number of bathrooms	1.3	0.9	1.1
Quality of inside maintenance (1=bad to 5=excellent)	4.1	4.0	3.9
Monumental status (0/1)	0.04	0.02	0.00
Presence of gas heater instead of central heating (0/1)	0.14	0.11	0.13
Presence of open fireplace (0/1)	0.06	0.14	0.17
Presence of garage (0/1)	0.08	0.10	0.30
Presence of garden (0/1)	0.34	0.66	0.67
House type (indicating any of the 14 possible types)	-	-	-
Spatial characteristics			
Presence of local open space in distance ranges: 0-10m; 10-25m; 25-50m; 50-75m and 75-100m (0/1);			
The average distance to local open space equals (m):	120	104	235
Distance to nearest regional open space (km)	1.7	0.6	0.5
Distance to city centre (km)	4.5	2.3	1.4
Urban attractivity index expressing availability of cultural, catering and retail facilities on 0 to 1 scale in 500m grid cells	0.31	0.14	0.15
Distance to nearest railway station (km)	2.2	1.8	2.6
Distance to nearest motorway ramp (km)	1.6	1.8	2.0
Presence of railway within 500m (0/1)	0.30	0.26	0.20
Presence of motorway within 500m (0/1)	0.13	0.29	0.25

2.4 Selection of study areas

The Dutch Randstad area consists of an interesting mix of urban and open areas and thus makes a natural study area for our analysis. This area in the western part of the country has a high population density and strong economic growth figures compared to the national averages. Urban growth seriously threatens the remaining open space here and has given rise to various restrictive zoning regimes, known as Buffer Zones and the Green Heart contour. These restrictive development zones have helped preserve part of the open space in the Randstad since their designation in the 1960's (Koomen *et al.*, 2008; Van Rij *et al.* 2008). The Randstad area has around 7 million people (GEMACA, 2002) and can certainly not be considered a single homogenous housing market. Separate, smaller case study areas must therefore be selected for the analysis. This is done because "[…] the market for a hedonic analysis […] should contain all the options available to potential buyers. If the market is defined larger than individuals actually choose from, then the regression results will be biased. On the other hand, by limiting the size of the market, the investigator loses information, so the estimation may become less efficient." (Geoghegan *et al.* 1997: 258). For the Netherlands, the Dutch Association of Real Estate Brokers distinguished 80 regions that they consider homogeneous local housing market areas. For the estimation of our model, three of these housing-market regions are selected that differ in size (e.g. as regards the urban area and number of inhabitants), amount and types of open space in the metropolitan area and composition of the housing market (i.e. number and types of houses available).

The selected regions of Amsterdam, Leiden and Het Gooi have in common that they border the Green Heart restrictive development zone (Figure 2). Amsterdam is the capital of the Netherlands and by far its largest city with over 800,000 inhabitants (CBS, 2005). The Amsterdam region covers a larger area than the city itself. To the north, Amsterdam cannot expand further because of nature protection laws and restrictive development zones (i.e. Buffer Zone Policy, European Bird- and Habitat Directives, and so on). Most urban growth in the past decades concentrated in the former agricultural areas west of the city. Currently, the city is also expanding by reclaiming land in the lake to the east of the city. Leiden, a city in the western part of the Randstad is situated near the major city of The Hague and has around 120,000 inhabitants (CBS, 2005). The city has a number of different types of open spaces in its surroundings: dunes and forest in the west, lakes to the north and the grasslands of the Green Heart to the east. Het Gooi is a region with a relative abundance of natural areas and it is situated between the big cities of Amsterdam, Utrecht, Amersfoort and Almere. The largest city in Het Gooi is Hilversum with over 80,000 inhabitants (CBS, 2005). Most of the open areas in Het Gooi are protected by nature laws, thus strongly limiting the options for urban growth.

The summary statistics of the data included in the analysis (Table 2) show that the average transaction price is highest in Het Gooi, but the average price per square metre is higher in Amsterdam. The latter region, on average, also holds the smallest houses in terms of surface area and number of rooms. Het Gooi has the largest share of the more expensive house types with more conveniences which is, for example, reflected by the fact that houses here, more often, have a garage, an open fireplace and a private open space in the form of a garden. Leiden offers the largest provision of local open space; more houses have a view of open space than in Het Gooi and in Amsterdam and the average distance to local open space is also shortest here. In Het Gooi, however, the average distance to regional open space is shortest; in Amsterdam this average distance is almost three times as large. Amsterdam has the highest level of urban facilities. Accessibility measures in the form of distance to railway stations and distance to motorway ramps indicate that Het Gooi is less well connected to the main forms of infrastructure than the other regions. The negative externalities associated with especially the presence of motorways do, however, also occur here.

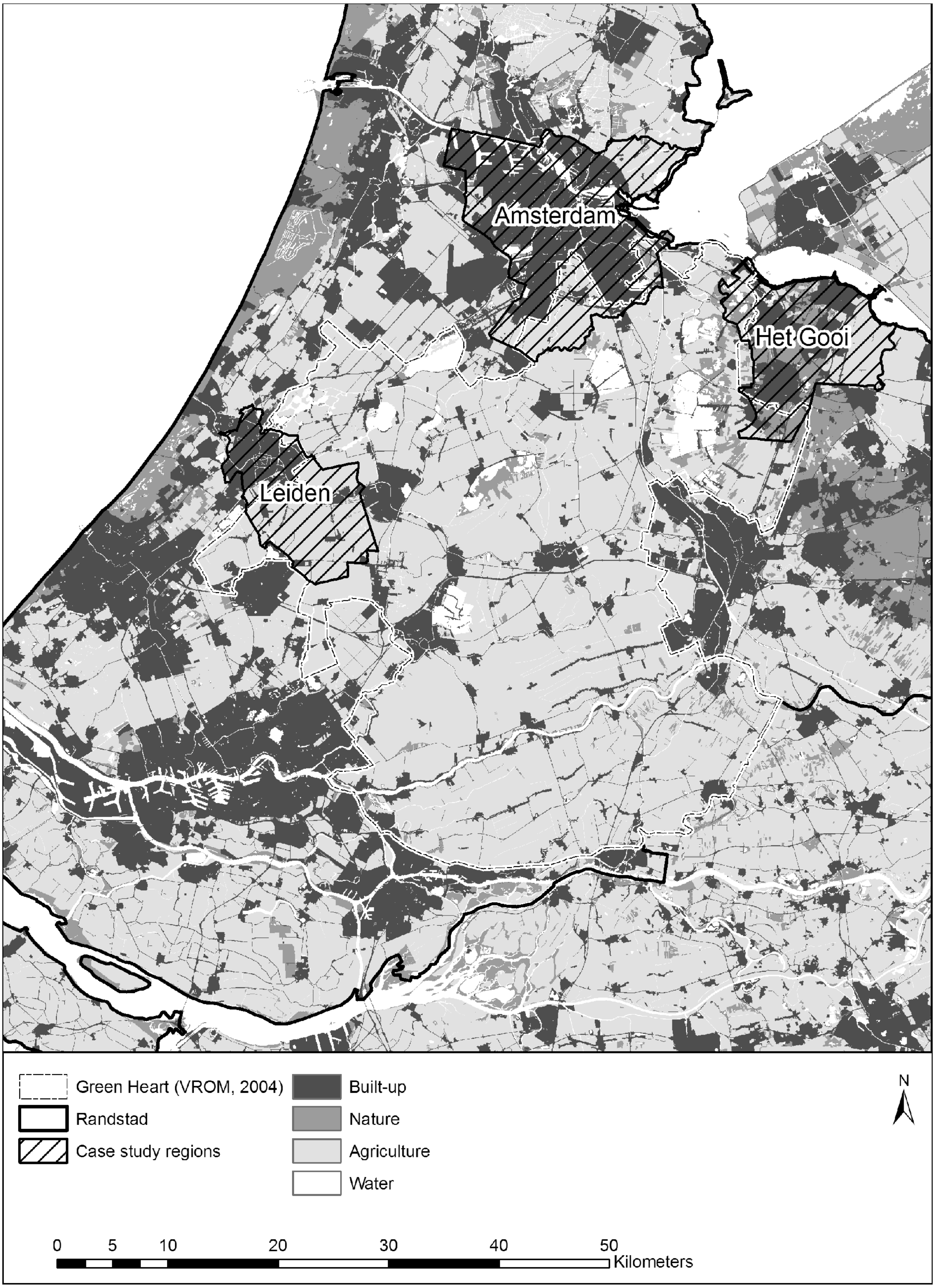

Figure 2. Location of the selected local housing market regions within the Dutch Randstad urban constellation.

3. ESTIMATION RESULTS

The statistical results for the estimated loglinear regression models for the three case-study areas are presented in Table 3. An alternative model specification with the distance to local open space defined as a continuous variable is included in Appendix I.

The models explain an impressive 78 percent or more of the observed variance in house prices. Especially the time dummies and house types prove to be important. The large price impact of Canalside houses is particularly interesting in the framework of this study as it indicates the importance of this type of open space. Furthermore, physical characteristics such as surface area and number of rooms have a considerable positive impact on house prices. The spatial characteristics seem to matter to a lesser extent with the exception of the amount of urban facilities that locally raises prices up to 59 percent.

The availability of local open space is found to have a significant positive contribution on house prices ranging from 4 to 8 percent, but this added value rapidly decreases to zero at a distance of around 50 metres from residences. Larger distances to local open space up to several hundreds of metres were tested in initial model specifications, but these did not yield significant results.

The contribution of larger areas of regional open space to house prices cannot be established unequivocally. In the housing-market areas of Het Gooi and Leiden houses closer to regional open space have a higher price (8.3 percent and 3.9 percent respectively) than identical property further away. In the larger agglomeration Amsterdam, however, there seems to be virtually no impact (0.1 percent). In the latter study, we investigated this limited impact more closely by specifying several model variations in which different areas of regional open space were distinguished. None of these model variations, however, indicated significant and robust differences in valuation for these areas that differed in, for example, dominant land-use type (e.g. forest or agriculture), cultural-historic value, recreational potential and accessibility. Another remarkable result in the greater Amsterdam area is the negative impact of the country house and farm types of residences. It should be noted, however, that only very few (16) observations relate to these two types in the studied period, making a reliable estimate difficult.

3.1 Spatial dependence

In spatial regression analysis, data has to be tested for spatial dependence as model estimates may prove to be biased or inefficient. Various standard global and local dependency tests are available for this purpose. Here, we use global tests related to two types of spatial dependence. The first type, lag or structural dependence, means that the prices of parcels that are close to each other are correlated. A spatial lag model therefore tries to control for this dependence between the explanatory variables. The second type, error dependence, means that the error terms for parcels that are close to each other are mutually dependent. A spatial error model estimates the effect of this heteroskedasticity (Anselin, 1988a).

We can describe both types of spatial dependence by reformulating our basic model (Eq. 1) into:

$$P = \rho WP + \alpha + \beta S + \gamma L + \tau G + \varepsilon \qquad (2)$$

where ε is equal to:

$$\varepsilon = \lambda W\varepsilon + \mu \quad \text{and} \quad \mu \sim N(0, \sigma^2) \qquad (3)$$

In this model, W represents a row-standardized spatial weight matrix, while ρ and λ are spatial-econometric coefficients that describe the importance of the spatial lag and spatial error component respectively.

Table 3. Estimation results for the three local case studies (period: 1997-2001)

	Amsterdam			Leiden			Het Gooi		
	Coef.	St.Err.		Coef.	St.Err.		Coef.	St.Err.	
Constant	8.348	(0.029)	***	9.554	(0.032)	***	10.060	(0.037)	***
Transaction characteristics									
Year 1998	0.161	(0.006)	***	0.105	(0.006)	***	0.092	(0.008)	***
Year 1999	0.343	(0.006)	***	0.257	(0.006)	***	0.255	(0.008)	***
Year 2000	0.455	(0.007)	***	0.372	(0.006)	***	0.390	(0.008)	***
Year 2001	0.547	(0.010)	***	0.427	(0.012)	***	0.432	(0.014)	***
Free of transfer tax	0.089	(0.020)	***	0.084	(0.078)		0.208	(0.062)	***
Physical characteristics									
Building age	0.000	(0.000)	***	0.000	(0.000)		0.000	(0.000)	
Ln(surface area)	0.489	(0.005)	***	0.287	(0.006)	***	0.226	(0.005)	***
Ln(number of rooms)	0.336	(0.006)	***	0.310	(0.009)	***	0.341	(0.010)	***
Number of bathrooms	0.050	(0.003)	***	0.025	(0.004)	***	0.043	(0.004)	***
Inside maintenance	0.116	(0.003)	***	0.107	(0.004)	***	0.096	(0.004)	***
Monumental status	0.062	(0.011)	***	0.143	(0.015)	***	0.316	(0.038)	***
Gasheater	-0.103	(0.006)	***	-0.079	(0.007)	***	-0.102	(0.008)	***
Open fireplace	0.035	(0.008)	***	0.004	(0.007)		0.073	(0.007)	***
Garage	0.088	(0.008)	***	0.074	(0.008)	***	0.118	(0.007)	***
Garden	0.070	(0.005)	***	0.007	(0.007)		-0.046	(0.008)	***
House type									
Farmhouse	-0.401	(0.109)	***	0.032	(0.054)		0.463	(0.028)	***
Country house	-0.507	(0.085)	***	0.375	(0.041)	***	0.755	(0.021)	***
Canalside house	0.563	(0.023)	***	0.373	(0.023)	***	0.743	(0.249)	***
Manor house	0.235	(0.009)	***	0.214	(0.007)	***	0.286	(0.012)	***
Villa	0.262	(0.021)	***	0.440	(0.017)	***	0.430	(0.009)	***
Bungalow	0.168	(0.028)	***	0.243	(0.021)	***	0.429	(0.022)	***
Split-level house	0.182	(0.052)	***	0.306	(0.062)	***	0.168	(0.059)	***
Drive-in house	0.219	(0.024)	***	0.142	(0.053)	***	-0.103	(0.032)	***
Practitioner's house	0.380	(0.032)	***	0.143	(0.044)	***	0.146	(0.055)	***
Ground floor apartment	0.072	(0.009)	***	-0.105	(0.013)	***	0.046	(0.022)	**
Ground & first floor apartment	0.071	(0.027)	***	0.023	(0.053)		0.240	(0.102)	**
Other apartments	0.023	(0.008)	***	-0.123	(0.007)	***	-0.071	(0.011)	***
Old people's home	-0.559	(0.035)	***	-0.641	(0.029)	***	-0.706	(0.031)	***
Spatial characteristics									
View of open space	0.044	(0.013)	***	0.035	(0.010)	***	0.077	(0.015)	***
Pres. of loc.open space 10-25m	0.051	(0.006)	***	0.080	(0.008)	***	0.029	(0.014)	**
Pres. of loc.open space 25-50m	0.002	(0.006)		0.064	(0.007)	***	0.017	(0.010)	*
Pres. of loc.open space 50-75m	-0.028	(0.006)	***	0.018	(0.007)	***	-0.010	(0.010)	
Pres. of loc.open space 75-100m	0.012	(0.006)	*	0.010	(0.006)		-0.015	(0.011)	
Dist. regional open space (km)	-0.001	(0.003)		-0.039	(0.007)	***	-0.083	(0.009)	***
Dist. to city centre (km)	-0.017	(0.000)	***	-0.006	(0.000)	**	-0.067	(0.000)	***
Urban attractivity index	0.588	(0.015)	***	0.370	(0.025)	***	-0.186	(0.038)	***
Dist. railway station (km)	0.011	(0.002)	***	-0.007	(0.003)	**	-0.009	(0.002)	***
Dist. motorway ramp (km)	0.025	(0.003)	***	-0.031	(0.003)	***	-0.022	(0.003)	***
Pres. of railway in 500m (0/1)	0.036	(0.005)	***	0.049	(0.006)	***	-0.057	(0.008)	***
Pres. of motorway in 500m (0/1)	-0.015	(0.006)	**	-0.109	(0.005)	***	-0.016	(0.006)	**
Number of observations		20,114			7,137			9,597	
Adjusted R-squared		0.78			0.85			0.84	

Note: *** = significant at 0.01; ** = significant at 0.05; * = significant at 0.10.
For the dummy variables the remaining categories (e.g. year = 1997) act as reference values.

For computational reasons tests for spatial dependence are performed on subsamples. We choose to test the transactions of the year 1998, leaving 4,611 (1,928; 2,279) observations for Amsterdam (Leiden; Het Gooi) to be used. The Moran's I test statistic for spatial error is positive and significant for Amsterdam and Het Gooi. This indicates that the regression estimates are biased, as there is a positive correlation between the residuals of neighbouring housing units. The Lagrange Multiplier (LM) tests against the presence of spatial lag and error indicate that both forms of spatial dependence are present in the models for all three regions, although in Leiden spatial dependence is found to be less significant (Table 4). The level of the test values in particular in Amsterdam and Het Gooi shows that a spatial error model is more appropriate than a spatial lag model. We therefore estimate a spatial error model for each case study region, using a maximum likelihood approach to correct for spatial dependence (Table 5). The obtained λ values indicate that spatial error is indeed substantial and statistically significant in all study areas, meaning that some unobserved characteristics that are present on a local (i.e. neighbourhood) scale level are important.

When we focus on the corrected open-space related results it is apparent that in general the coefficients are fairly comparable in terms of sign and magnitude. This indicates that these specific results are not strongly influenced by spatial error. What is more, the deviations that can be observed in, especially, Amsterdam, are partly introduced by the smaller sample size rather than spatial error issues. We tested this by taking as a sub sample the year 1999 instead of 1998, leading to different model results both in terms of magnitude and size.

Table 4. Results of Moran's I and Lagrange Multiplier (LM) tests for spatial dependence on subsamples from the year 1998

	Amsterdam		Leiden		Het Gooi	
	MI/DF	Value	MI/DF	Value	MI/DF	Value
Moran's I (error)	0.210	649 ***	0.017	34 ***	0.069	157 ***
LM (lag)	1	9081 ***	1	12 ***	1	872 ***
Robust LM (lag)	1	1255 ***	1	3 *	1	452 ***
LM (error)	1	312089 ***	1	630 ***	1	15365 ***
Robust LM (error)	1	304263 ***	1	621 ***	1	14945 ***
Nr. of observations		20,114		7,137		9,597

Note: *** = significant at 0.01; ** = significant at 0.05; * = significant at 0.10. MI denotes the Moran's I test-value, while DF indicates the degrees of freedom in the Langrange Multiplier test. For technical details on the LM test and the model specification, see Anselin (1988b), Bera and Yoon (1993) and Anselin *et al.* (1996).

Table 5. Estimation results corrected for spatial dependence (error models)

	Full model (1997-2001)		Sub sample (1998)		Spatial error model (1998)	
	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.
Amsterdam						
View of open space	0.044	(0.013)***	0.011	(0.027)	0.069	(0.023)***
Pres. of loc.open space 10-25m	0.051	(0.006)***	0.025	(0.013)*	0.081	(0.012)***
Pres. of loc.open space 25-50m	0.002	(0.006)	-0.018	(0.011)	0.015	(0.010)
Pres. of loc.open space 50-75m	-0.028	(0.006)***	-0.043	(0.012)***	0.002	(0.011)
Pres. of loc.open space 75-100m	0.012	(0.006)*	-0.005	(0.014)	0.005	(0.012)
Dist. regional open space (km)	-0.001	(0.003)	0.004	(0.006)	0.096	(0.013)***
λ					0.982	(0.006)**
Number of observations		20114		4611		4611
R-squared		0.779		0.750		0.819
Leiden						
View of open space	0.035	(0.010)***	0.040	(0.017)**	0.041	(0.017)**
Pres. of loc.open space 10-25m	0.080	(0.008)***	0.063	(0.015)***	0.066	(0.015)***
Pres. of loc.open space 25-50m	0.064	(0.007)***	0.052	(0.012)***	0.057	(0.012)***
Pres. of loc.open space 50-75m	0.018	(0.007)***	0.009	(0.012)	0.012	(0.012)
Pres. of loc.open space 75-100m	0.010	(0.006)	0.019	(0.011)*	0.022	(0.011)*
Dist. regional open space (km)	-0.039	(0.007)***	-0.016	(0.013)	-0.012	(0.014)
λ					0.668	(0.087)**
Number of observations		7137		1928		1928
R-squared		0.854		0.850		0.853
Het Gooi						
View of open space	0.077	(0.015)***	0.111	(0.031)***	0.064	(0.030)**
Pres. of loc.open space 10-25m	0.029	(0.014)**	0.063	(0.028)**	0.044	(0.027)
Pres. of loc.open space 25-50m	0.017	(0.010)*	-0.010	(0.020)	-0.018	(0.019)
Pres. of loc.open space 50-75m	-0.010	(0.010)	-0.023	(0.020)	-0.031	(0.019)
Pres. of loc.open space 75-100m	-0.015	(0.011)	-0.001	(0.022)	-0.017	(0.021)
Dist. regional open space (km)	-0.083	(0.009)***	-0.074	(0.018)***	-0.084	(0.023)***
λ					0.940	(0.021)**
Number of observations		9597		2279		2279
R-squared		0.845		0.822		0.840

Note: *** = significant at 0.01; ** = significant at 0.05; * = significant at 0.10.

The main deviation in the corrected 1998 model is found for the impact of distance to regional open space in Amsterdam; living closer to regional open space now seems to (considerably) decrease and not increase house prices *ceteris paribus*. This initially suggests that people in this big city seem to prefer living in a central location with all associated facilities rather than in a more peripheral location closer to larger tracts of open space. The high λ value, however, indicates that other, unobserved aspects influence property values. These may relate to, for example, neighbourhood image or local noise disturbance or other spatial characteristics that are possibly correlated to the distance to open space. A similar study in the Amsterdam region indicated the negative impact of transport noise (Dekkers and Van der Straaten, 2008). The difference in results between the three case studies may also be explained by the fact that the type, perceived quality and accessibility of regional open space differs considerably between for instance Amsterdam and Het Gooi. Further research into the local differences of open-space valuation is recommended to address the uncertainties that relate to the presented outcomes.

4. CONCLUSION AND DISCUSSION

This study aims to quantify the non-economic value of open space that is relevant to spatial policy, making these values easier to consider in policy-making. The hedonic price method proved to be a useful tool to assess the impact of open space on residential property values. For this study open space is interpreted as being a non-urban area that provides opportunities for rest and recreation. Three different spatial scales are distinguished: 1) open spaces that are visible from home, 2) local level open spaces, and 3) larger regional level open spaces.

The estimation results indicate that the availability of local open space (a view of open space and/or the presence of local patches of open space) has a substantial positive impact on house prices. This contribution is most prominent within a relatively short distance range: the added value becomes negligible at a distance of around 50 metres from the investigated houses, depending on the case study area. This conclusion corresponds with the findings in similar national and international hedonic pricing studies (e.g. Visser and van Dam, 2006; Bolitzer and Netusil, 2000; Powe *et al.*, 1995), which conclude that the proximity to local open space has a positive effect on house prices. The price impact and its decline over distance differ considerably between studies, making it difficult to draw more specific conclusions without doing extensive statistical analysis (Brander and Koetse, 2007).

About the contribution of larger areas of regional open space to house prices we find inconclusive evidence. This contribution is substantial in Het Gooi, only marginal in Leiden and even negative in Amsterdam. In Het Gooi the obtained impact points out that house prices decrease on average about 8 percent with every kilometre they are located further from regional open space. The apparent disinterest or perhaps even dislike of regional open space in Amsterdam may indicate that house preferences in this major city differ from the other studied regions. In this major city people seem to prefer living in a central location with all its associated facilities rather than in a more peripheral location closer to larger tracts of open space. Alternatively these results may also indicate that this essentially regional characteristic is not well-suited to explain local house prices. The availability of regional open space may, in fact, be more important in determining regional house prices at the aggregated level of housing market regions than at the local level of individual houses. That the impact of regional open space availability differs considerably per housing market region has, to our knowledge, not been documented explicitly in other studies and offers interesting directions for further research. The hypothesis that citizens of major urban areas care less for the proximity of larger regional open space will be tested in the ongoing related stated preference analysis. Next to that, we recommend the further development of hedonic house price models that should include notions of, for example, accessibility and typologies of open space. Additional applications on different urban areas of varying sizes may also provide further insight in the value of regional open spaces.

Locally diverging impacts are also found for other specific characteristics, for example in Het Gooi where the presence of a garden and the urban attractivity index have an impact that differs significantly from the other regions. This, again, indicates the existence of considerable differences between housing-market regions and thus signals the importance of performing hedonic house price analyses at this specific scale level.

The clearly positive impact of local open spaces in the immediate vicinity of houses provides policy makers with additional arguments for the preservation of green spaces in new residential areas. The results can, in fact, be used in negotiations about a (partial) recovery of the construction and maintenance costs for the green spaces that increase the property values. The fact that the impact of open space is limited to fairly short distances can be used by project developers to optimize the design of new urban areas. It may, for instance, be profitable to have as much houses as possible located very near a central open space (i.e. within 50 metres), instead of attaching a patch of open space at the edge of an urban development. Based on these results one can also wonder whether the current trend in some Dutch cities towards urban densification at the cost of local (inner-city) open space, instead of urban expansion claiming regional open space, is a good development.

Regional open spaces also contribute to house prices, but the observed impact differs so much per region that it does not offer unequivocal arguments for new ready-made intervention strategies aimed at preserving open space. The fact that regional open space has a counterintuitive contribution to house prices in the Amsterdam region, of course, does not mean that regional open spaces hold little value in this area. It only indicates that people in general are not willing to pay more for a house in the vicinity of such larger open spaces. It is important to note that such open spaces may contain many other societal values that are not necessarily expressed in house prices. This clearly underpins the need for alternative valuation studies with different objectives and techniques.

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APPENDIX I

Table 1. Case study results of an alternative model specification using continuous distance to local open space

	Amsterdam		Leiden		Het Gooi	
	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.
Constant	8.331	(0.028) ***	9.560	(0.032) ***	10.060	(0.037) ***
Transaction characteristics						
Year 1998	0.160	(0.006) ***	0.104	(0.006) ***	0.091	(0.008) ***
Year 1999	0.342	(0.006) ***	0.257	(0.006) ***	0.256	(0.008) ***
Year 2000	0.454	(0.007) ***	0.372	(0.006) ***	0.390	(0.008) ***
Year 2001	0.547	(0.010) ***	0.427	(0.012) ***	0.431	(0.014) ***
Free of transfer tax	0.091	(0.020) ***	0.095	(0.079)	0.213	(0.062) ***
Physical characteristics						
Building age	0.000	(0.000) ***	0.000	(0.000)	0.000	(0.000)
Ln(surface area)	0.494	(0.005) ***	0.287	(0.006) ***	0.228	(0.005) ***
Ln(number of rooms)	0.334	(0.006) ***	0.314	(0.009) ***	0.338	(0.010) ***
Number of bathrooms	0.049	(0.003) ***	0.025	(0.004) ***	0.043	(0.004) ***
Inside maintenance	0.117	(0.003) ***	0.107	(0.004) ***	0.096	(0.004) ***
Monumental status	0.076	(0.011) ***	0.141	(0.015) ***	0.316	(0.038) ***
Gasheater	-0.104	(0.006) ***	-0.079	(0.007) ***	-0.103	(0.008) ***
Open fireplace	0.036	(0.008) ***	0.004	(0.007)	0.072	(0.007) ***
Garage	0.090	(0.008) ***	0.075	(0.008) ***	0.119	(0.007) ***
Garden	0.070	(0.005) ***	0.009	(0.007)	-0.048	(0.008) ***
House type						
Farmhouse	-0.379	(0.109) ***	0.033	(0.054)	0.473	(0.028) ***
Country house	-0.493	(0.085) ***	0.387	(0.041) ***	0.760	(0.021) ***
Canalside house	0.586	(0.023) ***	0.381	(0.023) ***	0.798	(0.248) ***
Manor house	0.234	(0.009) ***	0.217	(0.007) ***	0.284	(0.012) ***
Villa	0.261	(0.021) ***	0.445	(0.017) ***	0.429	(0.009) ***
Bungalow	0.166	(0.028) ***	0.248	(0.021) ***	0.431	(0.022) ***
Split-level house	0.185	(0.052) ***	0.313	(0.062) ***	0.169	(0.059) ***
Drive-in house	0.220	(0.024) ***	0.147	(0.053) ***	-0.101	(0.032) ***
Practitioner's house	0.380	(0.032) ***	0.147	(0.044) ***	0.148	(0.055) ***
Ground floor apartment	0.071	(0.009) ***	-0.101	(0.013) ***	0.043	(0.022) **
Ground & first floor apartment	0.071	(0.027) ***	0.030	(0.053)	0.257	(0.101) **
Other apartments	0.023	(0.008) ***	-0.117	(0.007) ***	-0.069	(0.011) ***
Old people's home	-0.549	(0.035) ***	-0.625	(0.029) ***	-0.698	(0.031) ***
Spatial characteristics						
Dist. local open space (km)	-0.032	(0.018) *	-0.296	(0.030) ***	-0.114	(0.019) ***
Dist. regional open space (km)	0.001	(0.003)	-0.039	(0.007) ***	-0.056	(0.009) ***
Dist. to city centre (km)	-0.017	(0.002) ***	-0.007	(0.002) ***	-0.062	(0.006) ***
Urban attractivity index	0.595	(0.015) ***	0.367	(0.025) ***	-0.143	(0.038) ***
Dist. railway station (km)	0.012	(0.002) ***	-0.006	(0.003) **	-0.010	(0.002) ***
Dist. motorway ramp (km)	0.025	(0.003) ***	-0.031	(0.003) ***	-0.020	(0.003) ***
Pres. of railway in 500m (0/1)	0.035	(0.005) ***	0.052	(0.006) ***	-0.045	(0.008) ***
Pres. of motorway in 500m (0/1)	-0.016	(0.006) **	-0.110	(0.005) ***	-0.020	(0.006) **
Number of observations	20,114		7,137		9,597	
Adjusted R-squared	0.78		0.85		0.84	

Note: *** = significant at 0.01; ** = significant at 0.05; * = significant at 0.10.
For the dummy variables the remaining categories (e.g. year = 1997) act as reference values.